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(54) **Method for laser soldering**

(57) There is disclosed herein a method for laser soldering, comprising the steps of: (a) providing an electronic component 10 having at least two terminations 12 thereon; a dielectric substrate 14 having a first surface 16 on a first side 18 thereof, a second surface 20 on a second side 22 thereof, and at least two mounting pads 24 arranged on the first surface 16 in matched relation with the terminations 12 of the electronic component 10; and a diode laser 50; (b) depositing solder paste 26 atop the mounting pads 24; (c) placing the electronic component 10 atop the substrate 14 such that each termination 12 rests generally atop its respective mounting pad 24; and (d) directing laser energy 70 from the diode laser 50 to at least one of the mounting pads 24 from the second side 22 of the substrate 14 for a predetermined time, such that the solder paste 26 atop the at least one of the mounting pads 24 is melted.

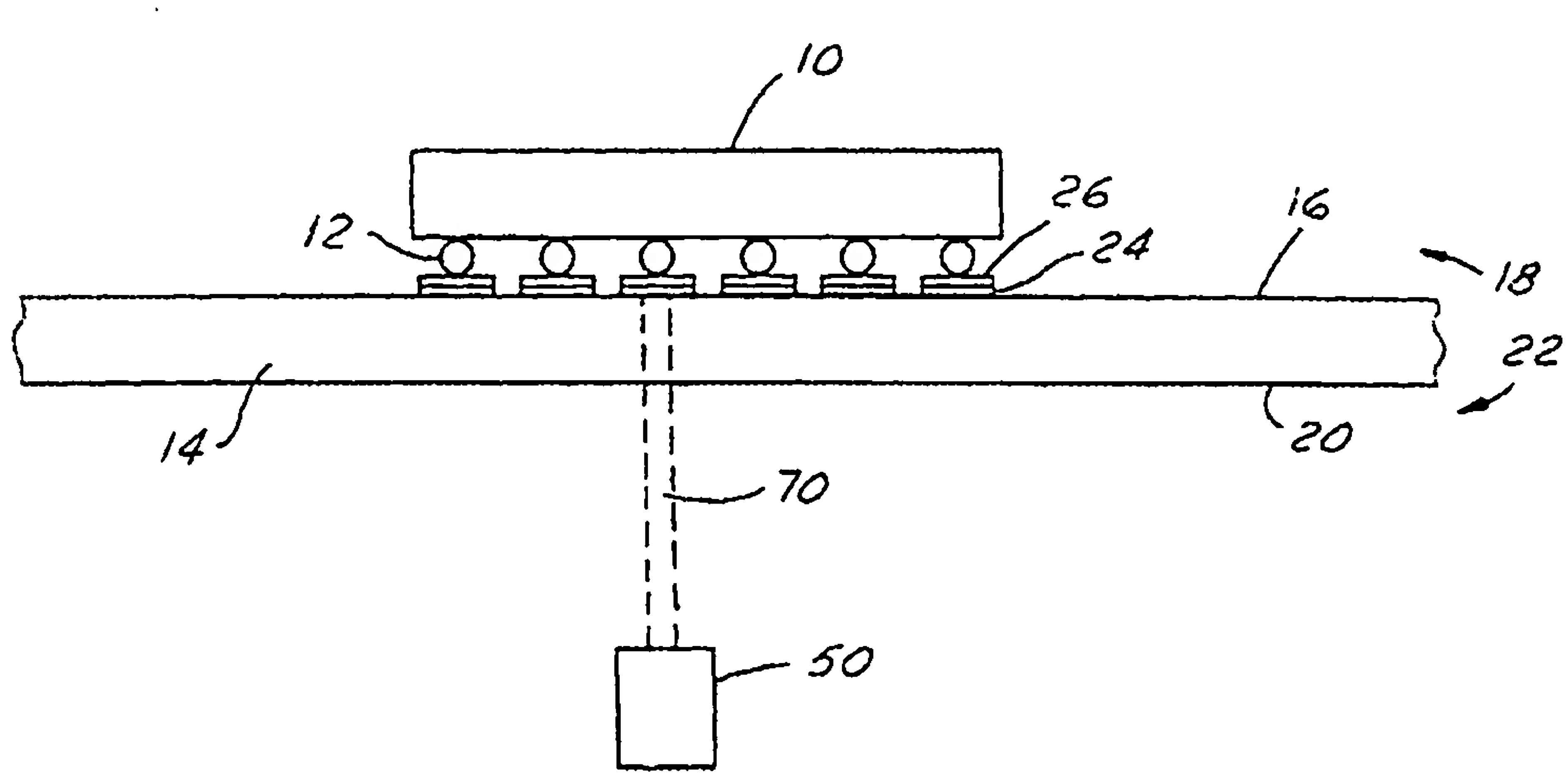


FIG. 2

Description

[0001] The present invention relates generally to laser soldering, and more particularly to a method for laser soldering electronic components to a circuit board substrate.

[0002] Electronic components are typically connected to circuit boards using either conventional reflow or wave soldering. An alternative and heretofore less widely used method is laser soldering, illustrated in FIG. 1. Laser soldering is often preferred over conventional reflow processing when the substrate is made of a material that is more temperature-sensitive than conventional laminated FR-4 glass-epoxy, such as a low melting point polymer or a thin flex circuit.

[0003] In conventional laser soldering, an electronic component 10 is placed atop a dielectric substrate 14 with the component terminations 12 resting atop solder pasted mounting pads 24, and a laser beam 70 from a YAG, Nd:YAG, diode, or other laser 50 is directed at one or more mounting pads 24 and/or solder depositions 26, in order to melt and reflow the solder paste 26 to form solder joints.

[0004] However, conventional laser soldering has always been limited to use with those components whose terminations remain visible after the component is mounted atop its respective solder-pasted mounting pads. These include components having conventional J-leads, gull-wing leads, or end terminations (such as in leadless chip components or LCCs) arranged about one or more sides of the component body. However, laser soldering has heretofore not been utilised on components whose terminations are arranged on an underside surface of the component, such as ball grid arrays (BGAs), pin grid arrays (PGAs), and the like. This is because the standard practice in laser soldering is to direct the laser beam 70 in a line-of-sight manner from a position above the substrate top surface 16 on which the component 10 is mounted, thus precluding its use on components whose terminations are "hidden" beneath the underside of the component when the component is mounted on its solder-pasted mounting pads. Thus, when a circuit board/substrate contains, for instance, J-lead, gull-wing, and BGA/PGA components and it is desired to use laser soldering, typical practice in this case would be to laser solder only the J-lead and gull-wing components, and to separately solder the BGAs/PGAs using a separate reflow process either before or after the laser soldering process. This requirement of a separate reflow step presents a significant drawback to the prospect of using laser soldering, not only because it requires the use of two separate soldering steps (i.e., reflow and laser soldering), but also because it typically requires the use of two separate solder pastes (i.e., one having a first melting point for the J-lead/gull-wing components, and another having a different melting point for the BGA/PGA components).

[0005] It would be desirable, therefore, to provide a method for using laser soldering with both (1) BGAs, PGAs, and other components having one or more terminations on an underside surface thereof, and (2) J-lead, gull-wing, end-terminated, and other such components.

[0006] The present invention overcomes the disadvantages of the prior art approaches by providing a method for laser soldering, comprising the steps of: (a) providing an electronic component having at least two terminations thereon; a dielectric substrate having a first surface on a first side thereof, a second surface on a second side thereof, and at least two mounting pads arranged on the first surface in matched relation with the terminations of the electronic component; and a diode laser; (b) depositing solder paste atop the mounting pads; (c) placing the electronic component atop the substrate such that each termination rests generally atop its respective mounting pad; and (d) directing laser energy from the diode laser to at least one of the mounting pads from the second side of the substrate for a predetermined time, such that the solder paste atop the at least one of the mounting pads is melted. It is an object and advantage that the method of the present invention may be used to laser solder components having terminations on an underside surface thereof. Another advantage is that the method of the present invention may laser solder such components without requiring modification of the component, terminations, mounting pads, solder paste depositions, substrate, or any other aspect of the electronic circuit assembly.

[0007] Yet another advantage is that the method of the present invention may be used not only for surface mount components having terminations on an underside surface thereof, but also for any other type of surface mount or plated through-hole component.

[0008] The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a side view of an electronic circuit assembly being laser soldered according to the prior art;
FIGS. 2-3 are side views of an electronic circuit assembly being laser soldered according to the present invention; and
FIG. 4 is a schematic of a diode laser system which may be used in conjunction with the present invention.

[0009] Referring now to the drawings, FIG. 2 shows an electronic circuit assembly being laser soldered according to the method of the present invention. First, an electronic component 10 having at least two termination 12 thereon is provided, along with a dielectric substrate 14 having a first surface 16 on a first side 18 thereof, a second surface 20 on a second side 22 thereof, and at least two mounting pads 24 arranged on the first surface in matched relation with the terminations of the electronic component. Also provided is a diode laser 50.

[0010] To assist the reader in understanding the present invention, all reference numbers used herein are summarised in the table below, along with the elements they represent:

10 =	Electronic component
12 =	Termination
14 =	Dielectric substrate
16 =	First surface of substrate
18 =	First side of substrate
20 =	Second surface of substrate
22 =	Second side of substrate
24 =	Mounting pad
26 =	Solder paste deposition
50 =	Diode laser
52 =	Laser energy source
54 =	Light pipe
56 =	Amplifier
58 =	Laser control unit
60 =	Emitting aperture
62 =	Housing for laser system
64 =	Means for positioning/aiming the aperture
66 =	Additional optical elements (e.g., mirrors)
70 =	Laser energy beam

[0011] After the aforementioned component 10, substrate 14, and diode laser 50 are provided, the second step is to deposit solder paste 26 atop the mounting pads 24. This may be done by conventional squeegee/stencil "silk-screening", compression printing through a stencil, dispensing, or any other known means. Once the pads 24 have been pasted, the third step is to then place the component 10 atop the substrate 14 such that each termination 12 of the component rests generally atop its respective mounting pad 24. This is typically accomplished by one or more automated/robotic pick-and-place machines, but may also be done manually or by other known means. This step is sometimes referred to in the electronics manufacturing industry as "populating" the substrate/circuit board.

[0012] Once the substrate has been populated, the fourth step is to then direct laser energy 70 from the diode laser 50 to at least one of the mounting pads 24 from the second side 22 of the substrate for a predetermined amount of time, such that the solder paste 26 atop the selected mounting pads 24 is melted. Once the solder/paste is melted, the beam 70 may be turned off and/or redirected to another one or more mounting pads, thereby allowing the melted solder paste to cool and a solid solder joint to form atop each of the at least one mounting pads 24 immediately after the fourth step. This provides a solder joint mechanically and electrically connecting the respective component termination 12 with its respective mounting pad 24.

[0013] This approach of lasing the mounting pad/solder paste 24/26 through the substrate 14 from the second side 22 -- i.e., from the side of the substrate opposite that on which a given component 10 is mounted -- is completely counterintuitive with respect to any conventional, prior art approach. As previously mentioned, the conventional approach for laser soldering is to lase line-of-sight from the same side of the substrate on which a component is mounted, as in FIG. 1. However, the laser energy produced by diode lasers is of a particular range of wavelengths such that the energy is readily absorbed by metals -- such as the mounting pads 24 and the solder particles in the solder paste 26 -- but is not readily absorbed by non-metallic, polymeric materials such as the substrate. This property of diode laser energy allows the laser beam to be directed through the substrate without damaging or otherwise deleteriously affecting the substrate, while allowing as much as 95% or more of the laser energy to pass through the substrate and to be delivered to the underside of the metallic mounting pads 24 and solder paste 26.

[0014] Diode lasers 50 are available in a variety of power configurations, generally from as little as 3 Watts to as much as 1000 Watts, with 3 to 40 Watts being most common. Because of the particular semiconductor nature of such devices, diode lasers produce a beam 70 whose wavelength is generally between 400 and 11,000 nm (0.4 to 11 μm), with 850 to 1000 nm being most typical. Given these power and wavelength ranges, along with the thickness and material type of the substrate to be lased, as well as the volume and melting point of the solder paste, the predetermined time required for lasing the mounting pad(s) so as to melt the solder paste can be determined. This time may also be affected by the temperature of the mounting pads 24 and solder paste 26 prior to being lased -- if the pads/paste have been pre-heated prior to lasing, such as by shuttling the populated circuit board/substrate through a pre-heat oven, then less time and/or laser energy would be required than if the pre-heating were not provided. Another factor affecting lase time (and/or laser energy output required) is the mass/thickness of the mounting pad(s) to be lased at a given time, and the degree to which the laser beam is focused/diffused with respect to the mounting pad(s). Typically, the time required to lase a given pad 24 in order to melt the paste 26 thereon is generally between 50 and 1000 milliseconds, with 300 to 1000 milliseconds being most typical.

[0015] For example, tests were conducted on several 3-mil-thick substrates of polyethylene naphthalate (PEN) film and polyimide (PI) film, each with standard copper mounting pads and circuit traces thereon. Each mounting pad was covered with a nominal deposition of eutectic tin/lead solder paste. Various BGA components with gold ball terminations were successfully laser soldered to the mounting pads on the PEN and PI films with acceptable solder joints resulting, using a 12 Watt, commercially available diode laser which produced a 960- to 980-nm beam. In the tests, only one mounting pad was soldered at a time, requiring about 500 milliseconds of lase time per mounting pad to produce acceptably reflowed solder joints. Tests were further conducted on 3-

to 8-mil-thick substrates of styrene-acrylonitrile (SAN), polyethylene terephthalate (PET), polyamide 6 (PA-6), polyamide 6/6 (PA-6/6), and polycarbonate (PC) using the same laser system, comparable wattage/wavelength settings, and lase times of 300 to 1000 milliseconds per mounting pad, with acceptable solder joints formed in each case.

[0016] The method of the present invention is particularly well suited for use with surface mount components 10 having terminations 12 on an underside surface thereof, such as BGAs and PGAs. However, the method may also be used with other surface mount components (e.g., J-leaded, gull-winged, and end-terminated components), as well as non-surface mount components such as dual in-line package (DIP) devices, conventional leaded resistors and capacitors, and other plated through-hole (PTH) components, as illustrated in FIG. 3.

[0017] The substrate 14 may be made from a wide variety of non-metallic, non-ceramic materials, such as epoxy, rigid to semi-rigid moulded, cast, or laminated polymers (e.g., polystyrene, polypropylene, acrylonitrile-butadiene-styrene (ABS), polyurethane, polysulfone, polyethersulfone, polyamide), or flexible moulded, cast, or laminated polymers (e.g., PI, polyetherimide, polyester, polyamide). Polymers used for the substrate may be thermoplastic or thermoset. It is preferable that the polymer material be unfilled or only minimally filled with fibre, talc, or other fillers, in order to maximise the transmissibility of laser energy through the substrate.

[0018] The diode laser 50 may comprise multiple elements or sub-systems, such as a source 52, light pipe 54, amplifier 56, central control unit 58, and emitting aperture 60 from which the beam exits, as illustrated in FIG. 4. The laser system 50 may also include: a housing 62 or other structural member for supporting one or more laser system elements; means 64 for positioning/orienting/aiming the emitting aperture 60; and/or additional optical elements 66 such as mirrors, lenses, beam splitters, collectors, amplifiers, conditioners, filters, optical connectors, additional light pipes, and the like. The aiming/positioning means 64 may be a robotic or automated positioning system or apparatus. The means 64 may aim/position only a portion of the laser system or, as shown in FIG. 4, it may aim/position the entire system; in either case, the aiming/positioning means 64 is preferably microprocessor-controlled.

[0019] The system 50 may be completely contained on the second side 22 of the substrate, as illustrated in FIG. 2, or may be positioned with elements/sub-systems on both the first and second sides 18/22, as illustrated in FIG. 3. Regardless of the specific configuration used, the main requirement as to the positioning of the system 50 and its elements is that the laser beam 70 be incident on the substrate 14 on its second surface 20, as shown in FIGS. 2 and 3.

[0020] It should be understood that, as used herein, the "first" surface 16 refers to that surface of the substrate 14 on which a given component 10 is mounted/soldered, and that the "second" surface 20 refers to that substrate surface, opposite the first surface, onto which the laser energy is incident and through which the beam 70 passes to the underside surface(s) of the mounting pad(s) 24. Also, the "underside" surface of the electronic component 10 is that component surface which is mounted face-to-face with the substrate first surface 16. For example, the "underside" surface of a BGA, PGA, flip-chip, or similar component is that surface having balls (e.g., solder, gold), pins, bond pads, or other terminations thereon.

[0021] Various other modifications to the present invention will, no doubt, occur to those skilled in the art to which the present invention pertains. For example, the first, second, and third steps described above can be combined into a single step of providing the component (s) 10, substrate/pads/paste 14/24/26, and diode laser system 50.

[0022] Also, one or both sides 18/22 of the substrate 14 may be populated with components 10, and the laser beam 70 may be used conventionally (i.e., to line-of-sight laser solder components 10 positioned on the same side of the substrate as the beam emitter 60), or according to the present invention (i.e., to laser solder components positioned on the side/surface of the substrate opposite the side/surface above which the beam emitter 60 is positioned), or both, as desired. When laser soldering according to the present invention is performed on both sides of a substrate, as illustrated in FIG. 3, a given side of the substrate may be a "first" side with respect to a particular component, and yet that same side of the substrate may be a "second" side with respect to another component. Thus, it should be apparent that the terms "first" and "second" are relative to a given component rather than being necessarily fixed with respect to all components. Other modifications not specifically mentioned herein are also possible and within the scope of the present invention. It is the following claims, including all equivalents thereof, which define the scope of the present invention.

Claims

1. A method for laser soldering, comprising the steps of:

   providing an electronic component (10) having at least two terminations (12) thereon; a dielectric substrate (14) having a first surface (16) on a first side (18) thereof, a second surface (20) on a second side (22) thereof, and at least two mounting pads (24) arranged on the first surface (16) in matched relation with the terminations (12) of the electronic component (10); and a diode laser (50);

   depositing solder paste (26) atop the mounting

pads (24);
placing the electronic component (10) atop the substrate (14) such that each termination (12) rests generally atop its respective mounting pad (24); and
directing laser energy from the diode laser (50) to at least one of the mounting pads (24) from the second side (22) of the substrate (14) for a predetermined time, such that the solder paste (26) atop the at least one of the mounting pads (24) is melted.

2. A method according to claim 1, wherein the diode laser (50) provides an output wavelength of generally between 800 and 1000 nm.

3. A method according to either claim 1 or claim 2, wherein the diode laser provides an output power of generally between 3 and 1000 Watts.

4. A method according to any one of the preceding claims, wherein the predetermined time is generally between 50 and 1000 milliseconds.

5. A method according to claim 1, wherein the diode laser output wavelength is generally between 850 and 1000 nm, the diode laser output power is generally between 3 and 40 Watts, and the predetermined time is generally between 300 and 1000 milliseconds.

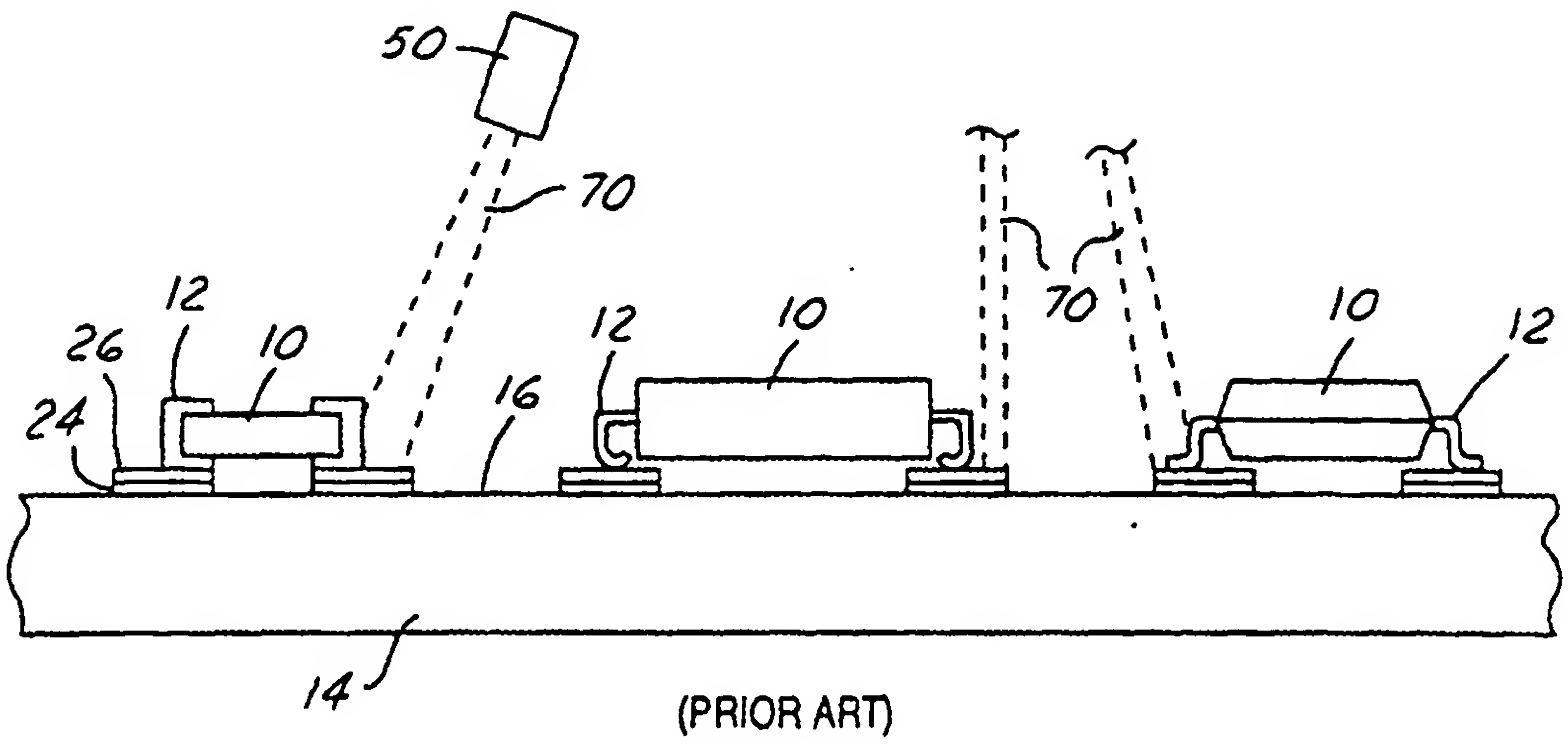
6. A method according to any one of the preceding claims, wherein the electronic component (10) is a surface mount component.

7. A method according to claim 6, wherein the electronic component (10) has terminations (12) on an underside surface thereof.

8. A method according to claim 7, wherein the -electronic component (10) is a ball grid array or pin grid array component.

9. A method according to any one of the preceding claims, wherein the dielectric substrate is made of a material selected from the group consisting of: epoxy; rigid to semi-rigid moulded, cast or laminated polymer; and flexible moulded, cast or laminated polymer.

10. A method according to any one of the preceding claims, further comprising the step of allowing a solid solder joint to form atop each of the at least one of the mounting pads (12) immediately after said step of directing laser energy, such that each solder joint mechanically and electrically connects its respective component termination (12) with its respective mounting pad (24).



(PRIOR ART)

FIG. 1

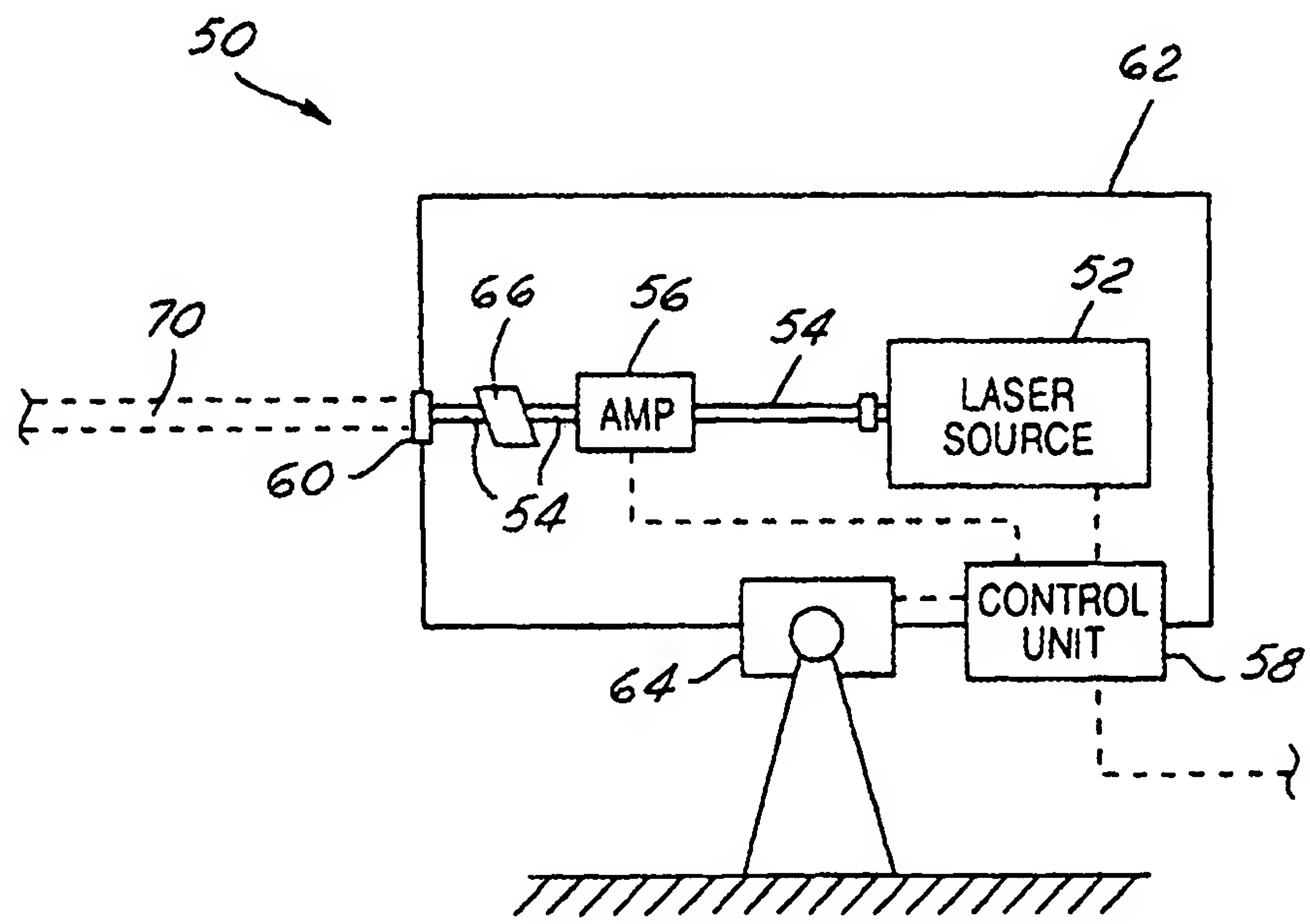


FIG. 4

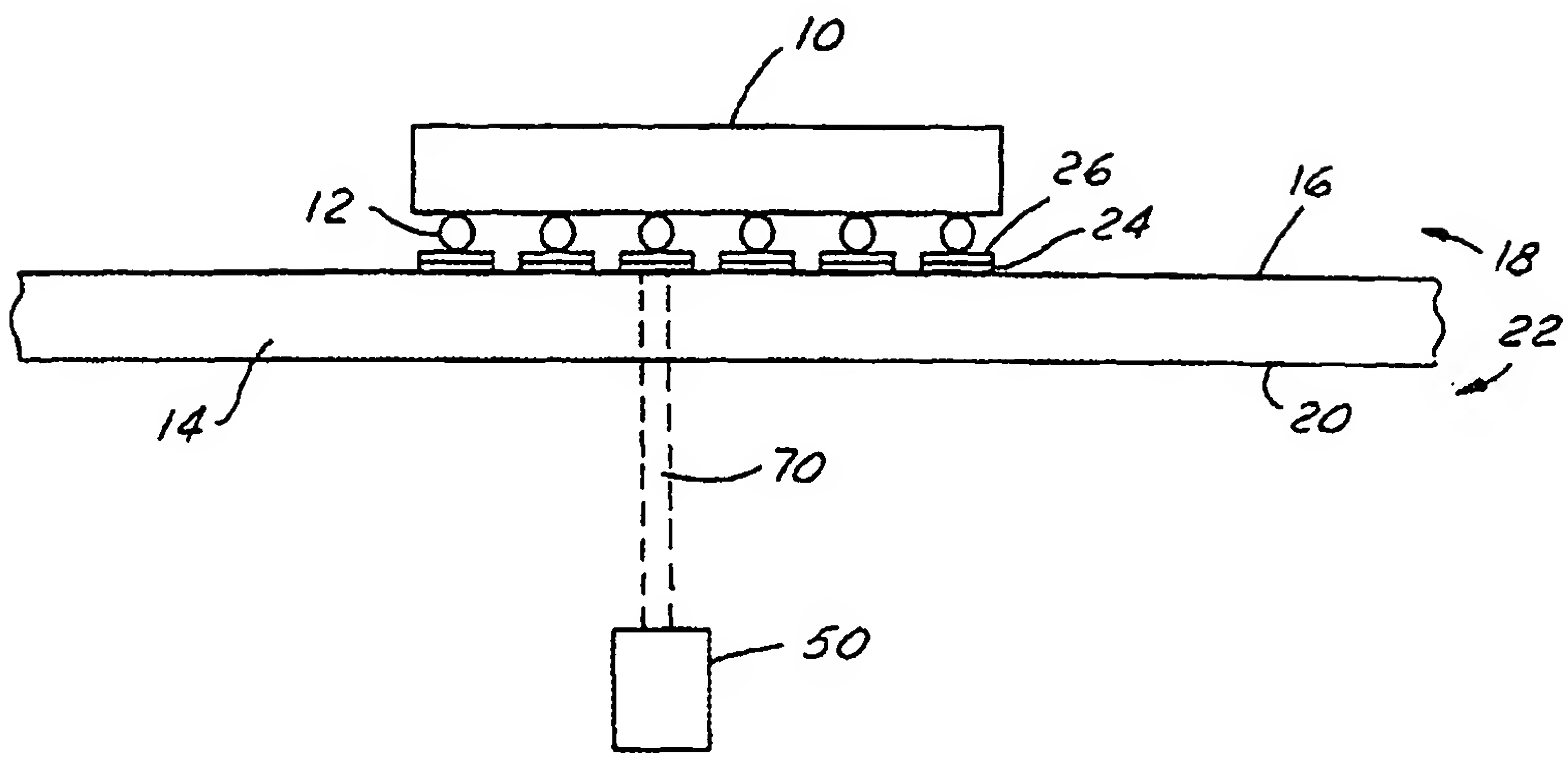

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FIG. 2

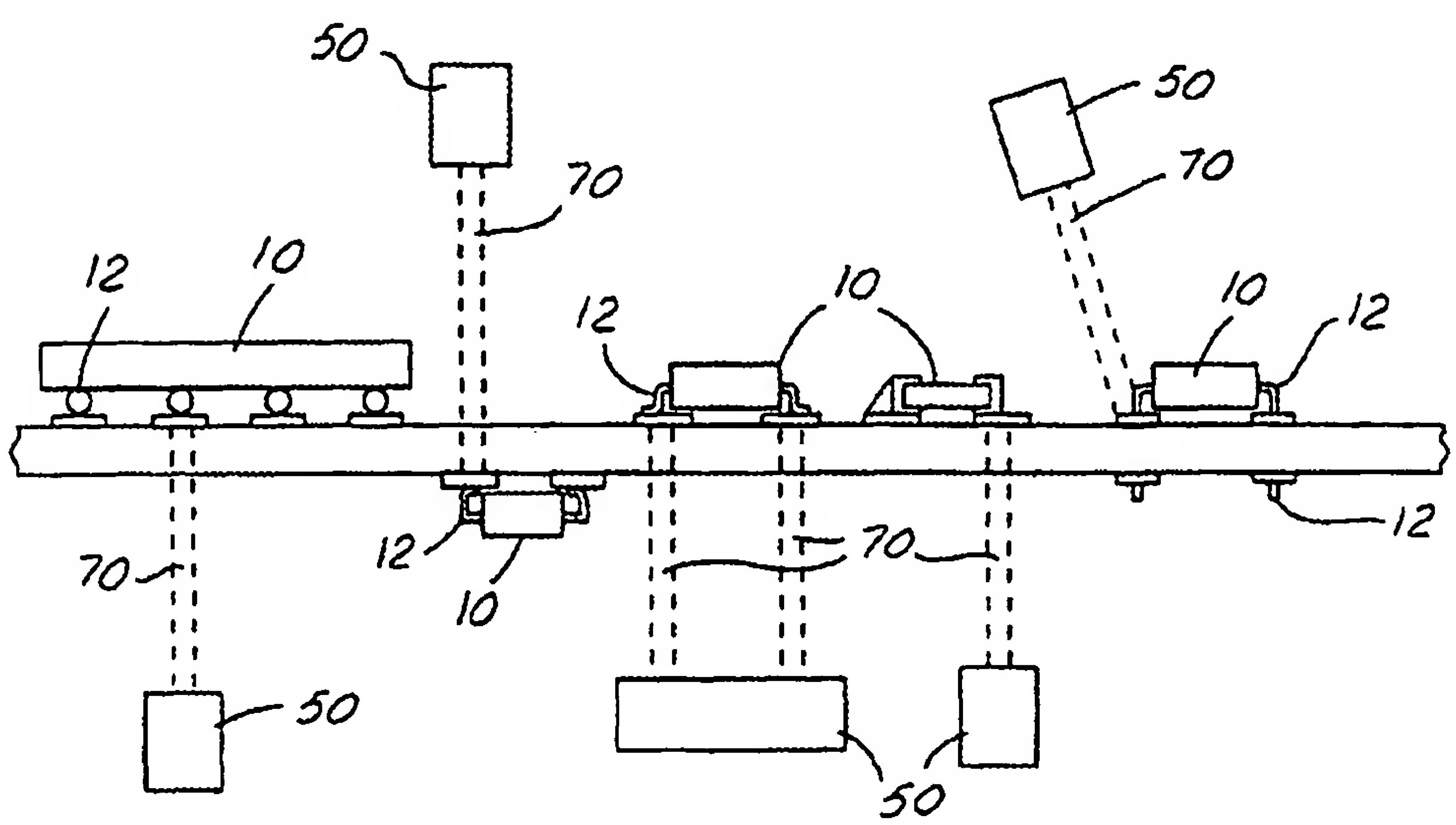
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FIG. 3